Enclosure 2
(Ref. Technical Letter F500-L14-012)

MITRE

Center for Advanced Aviation System Development

Alternative Runway Configuration for the Nuevo Aeropuerto Internacional de la Ciudad de México

Feasibility Analysis of Independent Departure Procedures

Prepared for

Aeropuertos y Servicios Auxiliares

January 2014

1. Introduction

As part of MITRE's support to Aeropuertos y Servicios Auxiliares (ASA), an analysis was performed to examine the feasibility of conducting independent instrument departures in both directions to three parallel runways at the Texcoco site. The runways would eventually be located in the proximity of the town of Texcoco, referred to in this document as the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM) site. MITRE has already determined the feasibility of conducting Category (CAT) I Instrument Landing System (ILS) approach procedures in both directions to three parallel runways at the NAICM site (refer to Enclosure No. 2 to MITRE Technical Letter F500-L14-004, November 2013, entitled *Alternative Runway Configuration for the Nuevo Aeropuerto Internacional de la Ciudad de México – Feasibility Analysis of Independent Approach Procedures)*.

This analysis represents a considerable effort. Therefore, any runway configuration changes should only take place after careful consideration by ASA. It is also important to note that while similar, these are <u>not</u> the same departure procedures MITRE delivered in July 2012 to the Dirección General de Aeronáutica Civil (DGAC). The 2012 departure procedures were based on a different runway configuration. See Section 2 for more background.

This document is organized into several sections. Section 2 provides background information on both MITRE's previously examined runway configuration [referred to in this document as the *MITRE-Recommended Runway Configuration (July 2012)*] and a new runway configuration requested by ASA (referred to in this document as the *NAICM Alternative 1 Runway Configuration*[1]*)*. Information on terrain and airspace issues is also included. Section 3 discusses MITRE's procedure development methodology, data used, and lists key assumptions considered in this analysis. Section 4 provides procedure design results for the *NAICM Alternative 1 Runway Configuration*. Finally, Section 5 provides a summary of MITRE's work and discusses next steps.

2. Background

Throughout the course of MITRE's overall support to Mexico's Secretariat of Communications and Transportation [Secretaría de Comunicaciones y Transportes (SCT)] over the past several years, MITRE has developed instrument procedures associated with various potential runway configurations pertaining to the NAICM project. That work was accomplished in coordination with officials from SCT *dependencias* such as ASA, the DGAC, and Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM).

The *MITRE-Recommended Runway Configuration (July 2012)*, shown in Figure 1, has a 002° True North Orientation and runway lengths as given in Table 1. It is the

[1] Note that in Enclosure 2 of MITRE Technical Letter F500-L14-004, November 2013, this configuration was referred to as the NAICM Alternative Runway Configuration.

preferred runway configuration due to procedure, airspace, and many other runway siting matters. This configuration was created after MITRE was informed by government officials in 2011 that additional land parcels had been acquired (or were in the process of being acquired) along the northeastern federal boundary line originally provided to MITRE by SCT. The additional land acquisition allowed for the possibility of shifting the easternmost pair of runways farther to the north, across the federal boundary line. However, for this runway configuration to be viable, a small land parcel, considered to be politically sensitive, must be acquired. This small land parcel is shown as the red triangular shaped area in Figure 1.

With the eastern set of runways shifted further north, the southern ends of all proposed runways are now at least 3 km from Lago Nabor Carrillo, which is a natural bird attractant site that can present a hazardous situation for arriving and departing aircraft operations. The 3 km minimum distance meets the United States (U.S.) Federal Aviation Administration (FAA) recommendation for separation between runways and wildlife attractants.

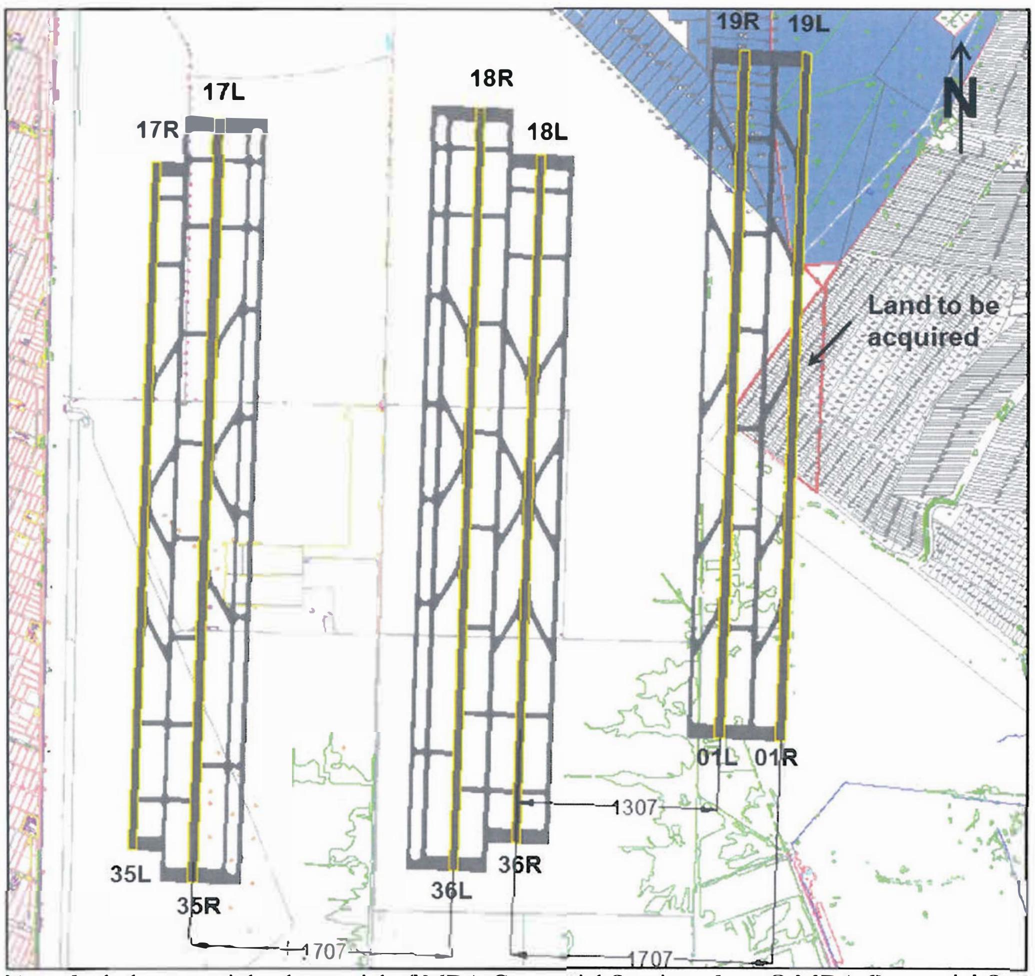


Figure 1. MITRE-Recommended Runway Configuration (July 2012)

Table 1. Runway Lengths

Runway	Length (m)
35L/17R	4500
35R/17L	5000
36L/18R	5000
36R/18L	4500
01L/19R	4500
01R/19L	4500

The recommended runway configuration shown in Figure 1 was developed under the assumption that additional land to the north and east of the boundary of federally-owned land would be acquired. Federal officials were confident at the time that the land required for this runway configuration would be purchased by the federal government. Nonetheless, ASA requested that MITRE examine an alternative runway configuration in the event the triangular area of land to the east (and impinging on Runway 01R and Runway 01L) may not be acquired.

In response to the request mentioned above, a new runway configuration was investigated by MITRE, and that configuration, referred to as the *NAICM Alternative 1 Runway Configuration,* is described in Enclosure No. 1 to MITRE Technical Letter F500-L14-004, November 2013, entitled *Alternative Runway Configuration for the Nuevo Aeropuerto Internacional de la Ciudad de México – Initial Assessment*[2].

The subject of this report is the triple independent instrument departure procedure design work performed for the *NAICM Alternative 1 Runway Configuration* shown in Figure 2. The specific runways for which the departures were designed for are highlighted in red. Runway lengths are unchanged from those given in Table 1.

Mountainous terrain surrounding the NAICM area (see Figure 3) complicates the development of instrument procedures, especially when considering triple independent instrument departures. In addition to the normal divergence requirements between independent runway departures (i.e., a combined 15°), MITRE also examined a concept referred to as "fanning". In a fanning situation, successive departure paths from the same runway diverge by 45° or more while still meeting the parallel runway divergence of 15°. This concept helps maximize departure capacity.

The minimum standard Climb Gradient (CG) for departures is 200 feet per nautical mile (ft/NM). Whenever obstacles generate a CG higher than standard, a CG higher than 200 ft/NM must be published.

[2] Note that in Enclosure 1 of MITRE Technical Letter F500-L14-004, November 2013, this configuration was referred to as the NAICM Alternative Runway Configuration.

During MITRE's previous project work it became apparent that the Santa Lucía Military Base and the Special Use Airspace (SUA) MMR-100 and MMR-112, as well as other SUAs located farther away from the base, would need to be relocated before the new airport opens. See Figure 4 (SUAs MMR-100 and MMR-112 shown in green). Leaving the base and its SUAs in place would create a difficult and highly complex airspace environment (e.g., intermingling and crossing of routes, increased traffic density on those routes, and varying aircraft performance characteristics). Additionally, accommodating operations at Santa Lucía Military Base would adversely impact runway capacity at the new airport. Therefore, MITRE, in joint collaboration with SENEAM, mutually agreed that Santa Lucía Military Base and all of its associated SUAs should be relocated.

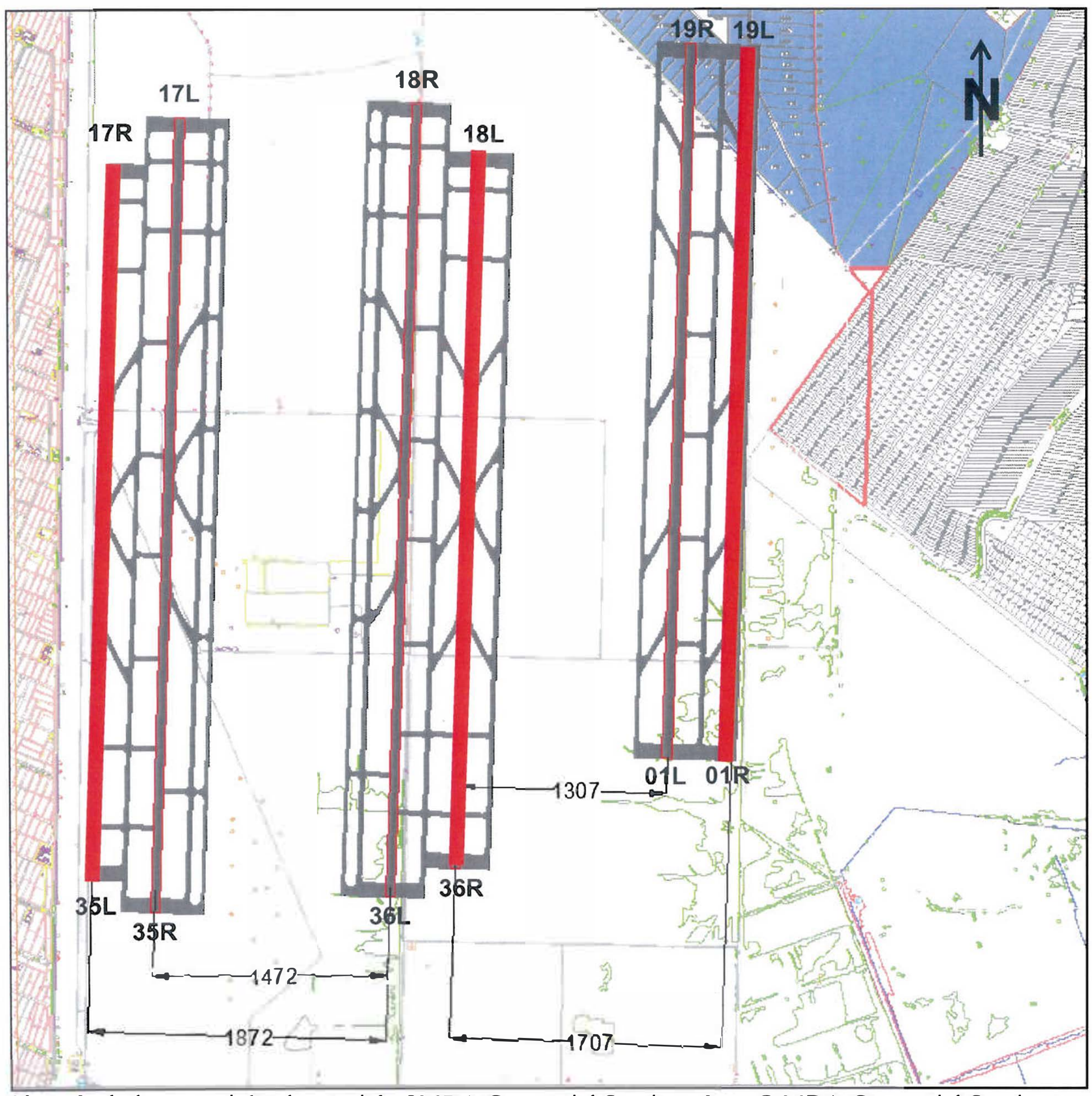
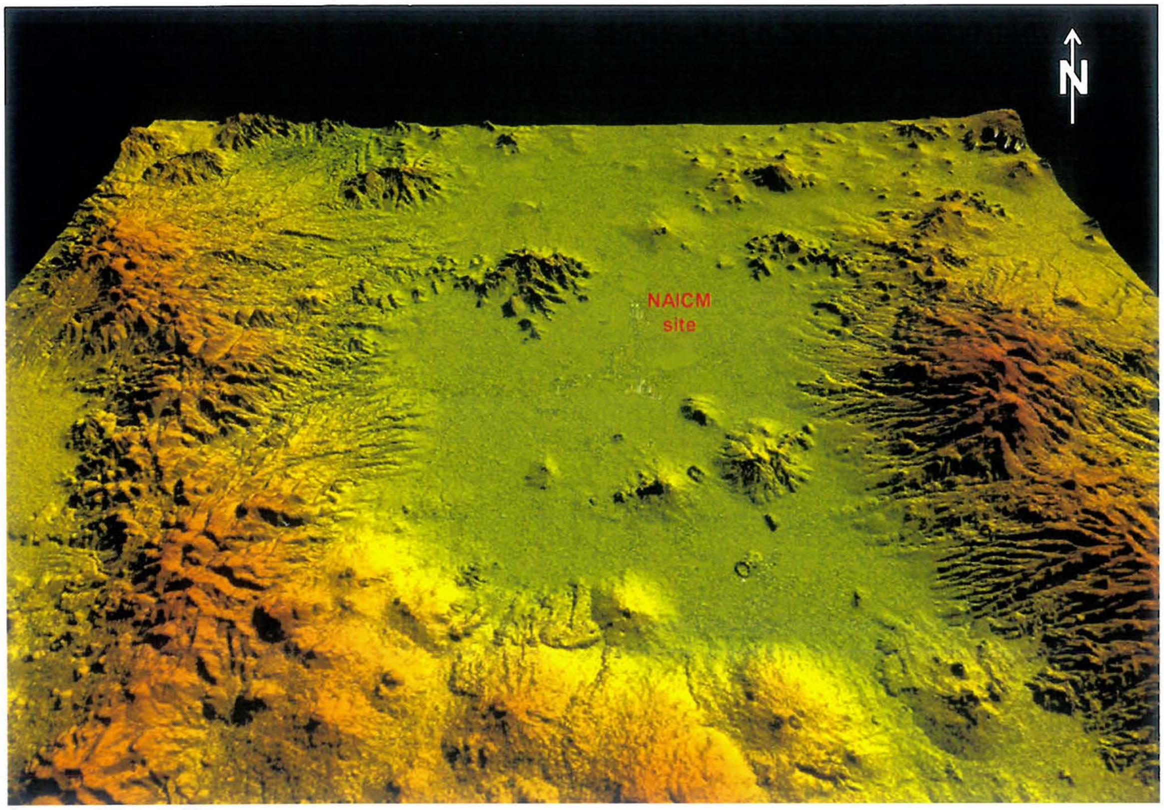


Figure 2. NAICM Alternative 1 Runway Configuration



Source: Global Mapper

Figure 3. High Terrain Surrounding the NAICM Area

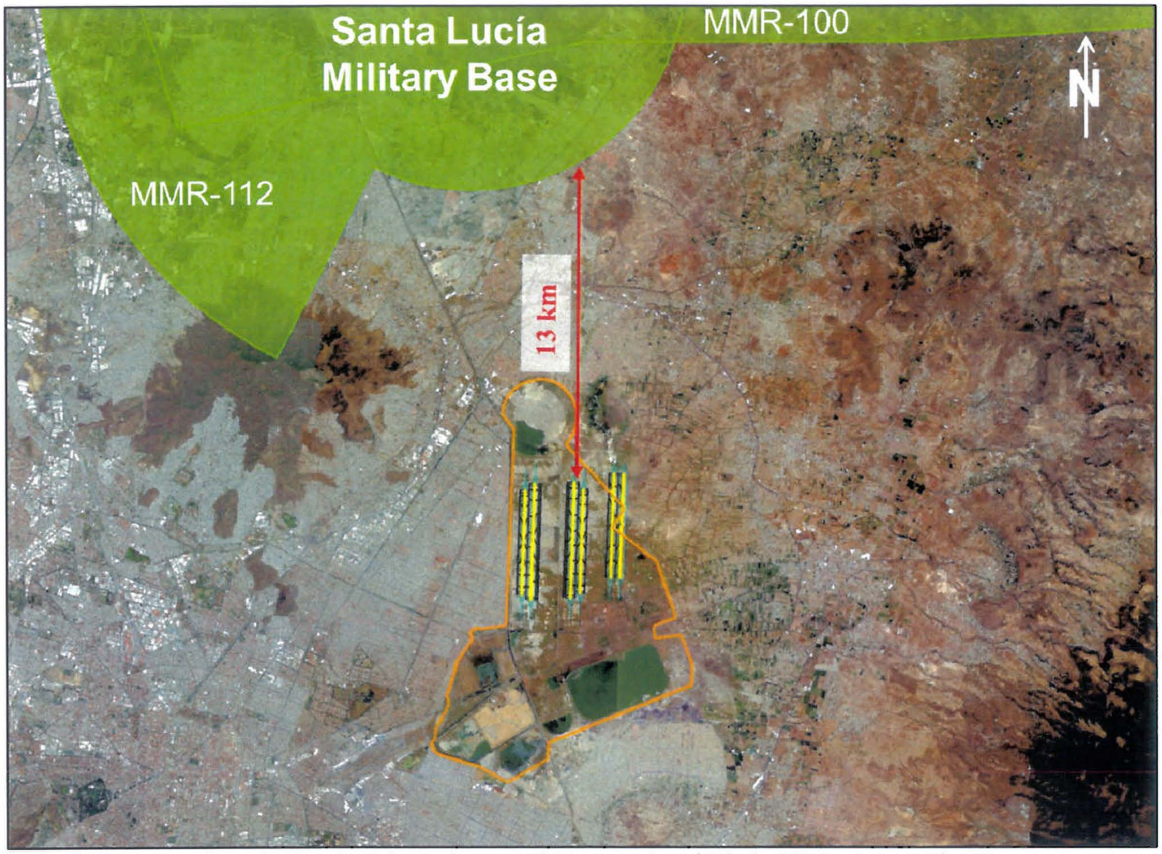


Figure 4. Santa Lucía Military Base and SUAs in Relation to the NAICM Site

3. Methodology, Data Used, and Assumptions

In general, instrument procedures are not only developed for a specific runway configuration, but also for specific modes of operation. In the case of NAICM, MITRE examined the feasibility of triple independent instrument departure procedures, which will maximize ultimate runway capacity.

Many factors must be considered in the development of instrument procedures, especially when considering triple independent operations to parallel runways. The departure procedures discussed in this document were developed in accordance with the U.S. Standard for Terminal Instrument Procedures (TERPS) criteria, which Mexico has used for many years.

Wherever possible, MITRE attempted to work within the existing airspace structure by using existing Navigational Aids (NAVAIDs), airways, fixes, etc. However, as a part of the design, MITRE defined a future Very High Frequency Omnidirectional Range (VOR)/Distance Measuring Equipment (DME) to be located at the NAICM site to assist in navigating. Additionally, the procedures described in this report were designed under the assumption that the existing VOR/DMEs at both Mexico City International Airport

(AICM) and the Santa Lucía Military Base, along with several other existing NAVAIDs (as indicated in the procedures described below), would remain operational.

During a previous study, MITRE discovered that the Minimum Vectoring Altitude Chart (MVAC), which depicts the lowest altitudes at which air traffic controllers can radar vector aircraft, would not adequately support the anticipated future instrument procedures at the new airport. Therefore, in close coordination with SENEAM, MITRE developed a new MVAC for a combined NAICM/Toluca Terminal Maneuvering Area to support future operations. This is important as some of the departure procedures designed by MITRE terminate at points in space at or above minimum vectoring altitudes from which air traffic controllers will begin providing radar vectors.

The development of instrument procedures is a complex process. Increased levels of required accuracy and electronic databases (e.g., obstacle data) make automation a necessity. MITRE uses a variety of software tools when designing procedures, such as AutoCAD and PDToolKit. The former is a well-known tool, while the latter is a specialized tool used to develop and evaluate instrument procedures and conduct obstacle assessments.

An up-to-date, robust, and accurate database of both aeronautical and obstacle information is essential in the development of instrument procedures. In 2010, a satellite-based survey of the area was conducted[3]. Information from this survey and other sources, such as the Aeronautical Information Publication (AIP) of Mexico, were used to develop a highly detailed basemap within AutoCAD. MITRE uses the basemap to formulate, test, and analyze various procedure design options in order to determine feasibility. A new satellite-based survey is going to be commissioned by MITRE to be used by SENEAM and MITRE to verify that no problematic man-made obstacles have been erected since the 2010 survey.

To determine the feasibility of departure procedures at NAICM, certain assumptions regarding important aeronautical factors were made:

- Existing AICM will close once NAICM opens
- Santa Lucía Military Base and its associated SUAs will be relocated before NAICM opens
- The existing VOR/DMEs located at existing AICM and at Santa Lucía Military Base will remain in their current locations and continue to operate (even after existing AICM closes and Santa Lucía Military Base is relocated). MITRE must be informed as soon as possible if this assumption is not correct as the absence of these VOR/DMEs will affect MITRE's procedure design work.

[3] The survey is composed of 3 areas: 1) the Photogrammetric Survey Area (PSA), which approximates the NAICM boundary, 2) an Area A and 3) an Area B. Within the PSA is a rectangular box that encompasses all potential runway configurations. Area A extends from the boundary of the rectangular area to 10 km. Area B extends from the boundary of Area A an additional 35 km. As part of the satellite survey, site visits were conducted to collect and confirm additional information.

- NAVAIDs are capable of and can be flight checked to ensure they are adequate to meet the departure design requirements
- Information collected from the 2010 satellite-based survey took precedence over all other obstacle data sources
- MITRE assumed an Adverse Assumption Obstacle (AAO) to account for any unidentified man-made obstacles. A 60 m above ground level AAO was applied from the outer boundary of Area A outward to a distance of 5 NM beyond the MVAC boundary.
- Future airport facilities (e.g., terminal buildings, aircraft parking stands, aprons, and other airfield components) were not considered. MITRE assumed that future airport facilities would not impact any departure obstacle clearance surfaces or result in NAVAID signal interference.
- The new combined NAICM/Toluca MVAC (jointly developed by SENEAM and MITRE) will be implemented

4. Instrument Departure Procedure Development

MITRE developed triple independent instrument departure procedures in both directions for the first three runways of the *NAICM Alternative 1 Runway Configuration* (i.e., Runways 35L/17R, 36R/18L, and 01R/19L). See Figure 5. Which runway of the center pair should be constructed first is still a matter of discussion. However, for this study, MITRE assumed that Runway 36R/18L would be constructed first.

MITRE examined two separate departure procedures from each runway end, except the center runways (36R/18L) and Runway 35L. In a three-runway configuration, the center runways have virtually no option other than to proceed straight ahead. Therefore, only a single straight ahead departure was considered for Runways 36R and 18L. For Runway 35L, MITRE examined three departure procedures. These additional departures allow for fanning between departures from the same runway.

Recent U.S. FAA policy eliminated the need to differentiate between CGs for either ATC purposes or obstacle clearance. The reasoning behind this decision is that in the U.S. there is no way to determine if the altitude depicted on a Standard Instrument Departure chart is for obstacle clearance or to meet an ATC requirement. Therefore, the crossing altitude must be complied with unless ATC intervenes and assumes responsibility for obstacle avoidance. This document follows that same philosophy.

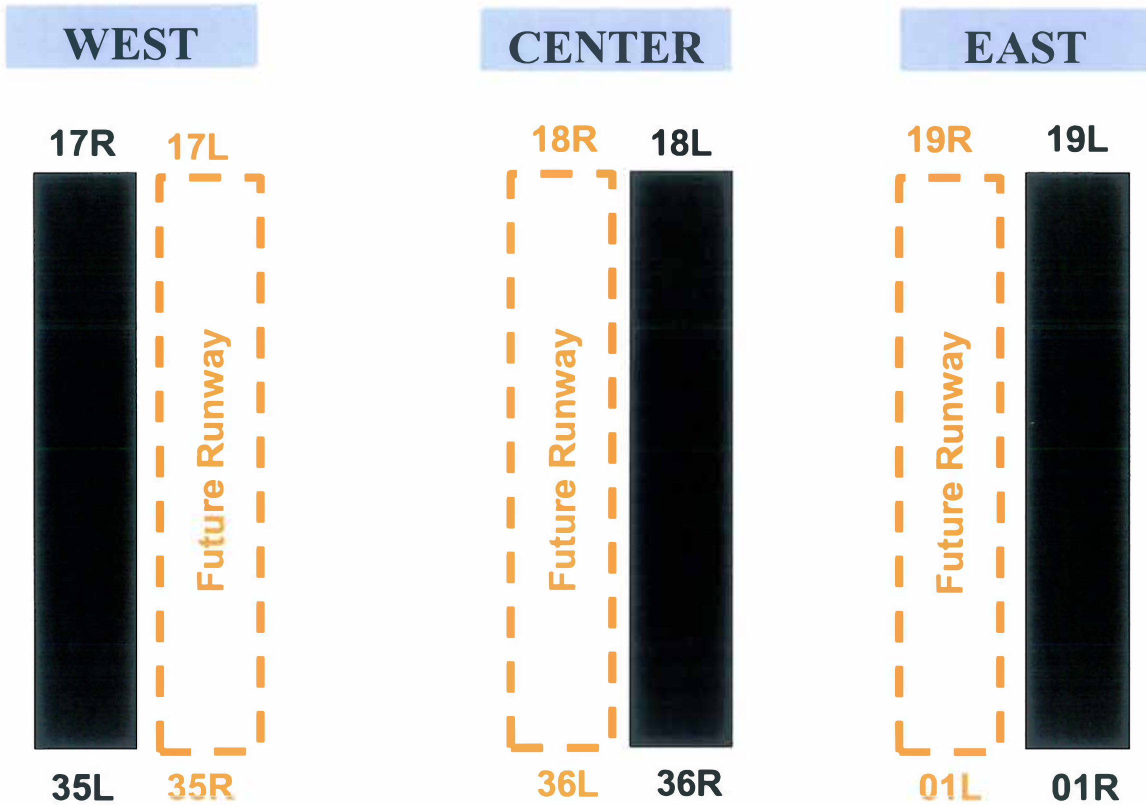


Figure 5. Potential Opening-Day Runways (Shown in Black) at NAICM

The objective of MITRE's procedure design work is to demonstrate the feasibility of conducting triple independent instrument departure procedures. Whenever possible, departure procedures should be developed that do not incur CGs above standard[4]. However, due to high terrain most of the departure procedures at NAICM will require a CG.

It is worthwhile mentioning that ASA reported to MITRE an intention by the Comisión Federal de Electricidad of installing a power line in the proximity of the NAICM site. MITRE is waiting for coordinates and elevations of the power line to analyze its impact or possible relocation.

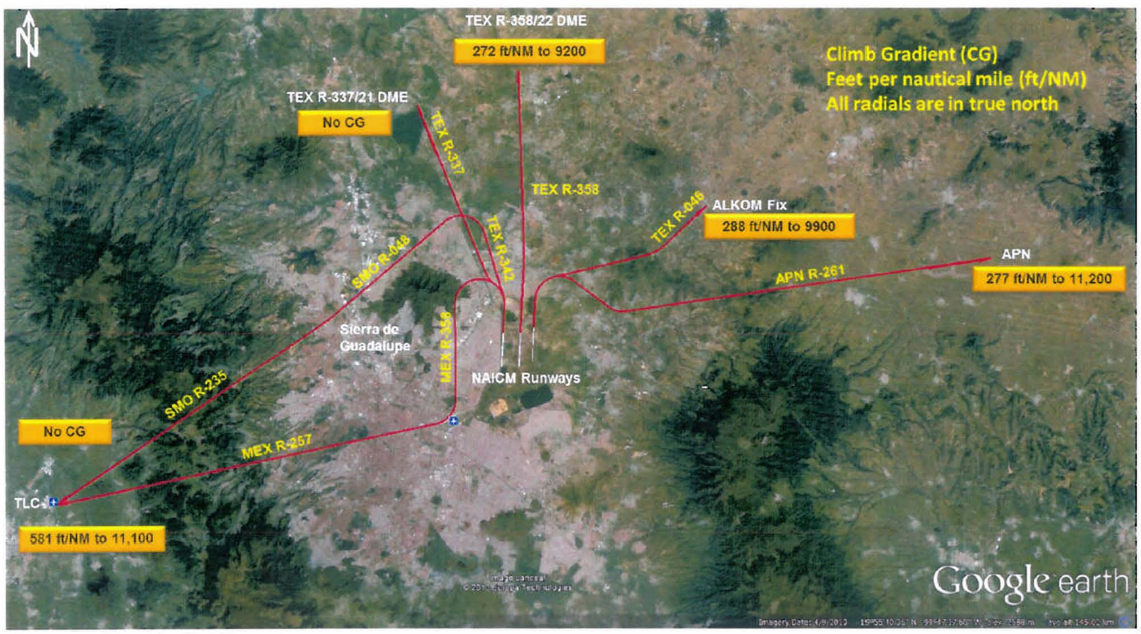
4.1 Instrument Departure Procedures to the North

Figure 6 shows the nominal departure paths for procedures to the north for the *NAICM Alternative 1 Runway Configuration*. The following paragraphs provide information about the individual departures including takeoff minimums, departure instructions, and any associated CGs. All headings and radials denoted on these figures are based on true north.

[4] A standard CG is considered to be 200 ft/NM.

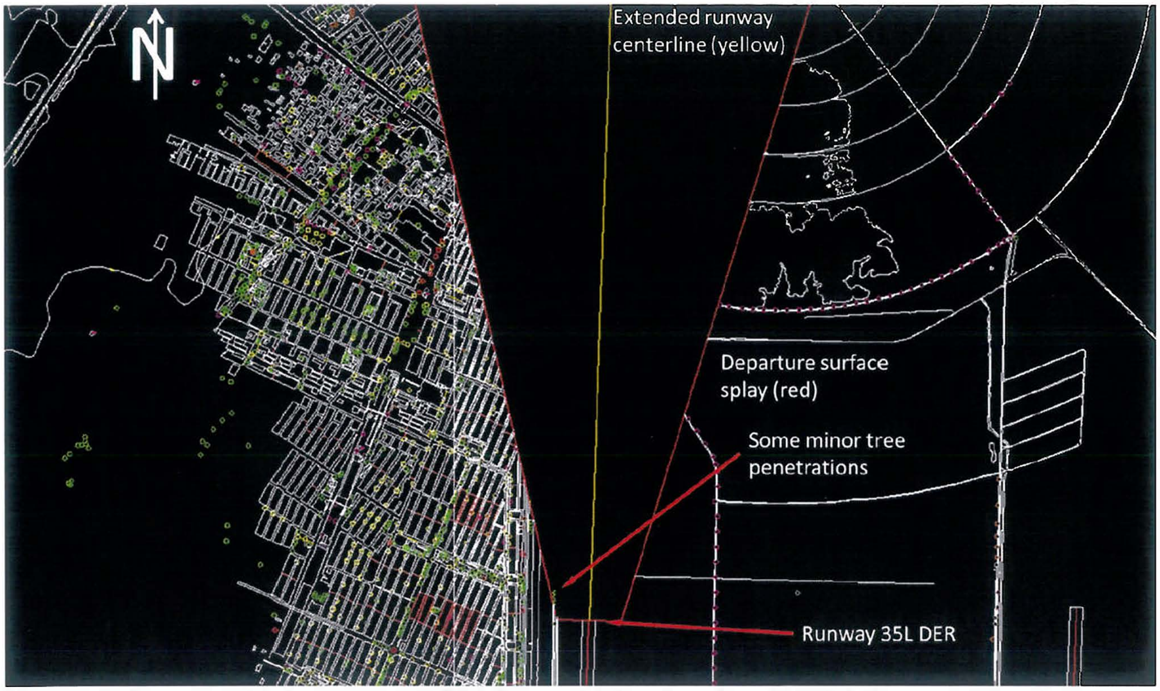
With the runways shifted west from the previous runway configuration, a primary concern was how road traffic on the major highway and other obstacles near the beginning of the densely populated city just west of the NAICM site would impact departures from Runway 35L. For Runway 35L, trees near the departure end penetrate the departure surface by approximately 13 ft and require removal. See Figure 7.

MITRE also assumed a 15 ft vehicle on the highway for a height of 7314 ft. The departure surface height at the point of intersection with the highway is 7338 ft. Finally, city building heights at the point of intersection with the departure surface are approximately 7330 ft. The departure surface height at the point of intersection is 7346 ft. As a result, highway traffic and city buildings do not penetrate the departure surface.



Source: Google Earth

Figure 6. NAICM Alternative 1 Runway Configuration Nominal Departure Paths: North Flow



Note: Includes copyrighted material of MDA Geospatial Services, Inc. © MDA Geospatial Services, Inc. (2010) - All Rights Reserved.

Figure 7. Runway 35L Penetrations

4.1.1. Runway 35L

The following sections provide a brief description of the departure procedures to include takeoff minimums and departure instructions.

4.1.1.1. TLC Departure (hard left turn)

At the TLC VOR/DME, aircraft will be directed to the south.

Takeoff Minimums: Standard[5] with a minimum CG of 581 ft/NM to 11,100 ft.

Departure Instructions: Climbing left turn to intercept MEX VOR/DME R-358 (T) to MEX VOR/DME, then via MEX VOR/DME R-257 (T) to TLC VOR/DME, cross TLC VOR/DME at or above 15,000 ft, thence[6]…

4.1.1.2. TLC Departure (turns southwest after rounding north of Sierra de Guadalupe)

At TLC VOR/DME, aircraft will be directed to the south.

Takeoff Minimums: Standard

[5] U.S. air carrier standard civil takeoff minimums are based on aircraft type. Fixed wing aircraft with 2 or fewer engines require 1 Statute Mile (SM) visibility. Fixed wing aircraft with more than 2 engines require ½ SM visibility.

[6] Unless noted otherwise, instructions after the word "thence" are to be issued by ATC.

Departure Instructions: Climbing left turn to intercept TEX VOR/DME R-342 (T), then intercept SMO VOR/DME R-048 (T) to SMO VOR/DME, then via SMO VOR/DME R-235 (T) to TLC VOR/DME, cross TLC VOR/DME at or above 15,000 ft, thence…

4.1.1.3. Northwest Departure

At TEX VOR/DME R-337/21 DME, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., northwest bound).

Takeoff Minimums: Standard

Departure Instructions: Climbing left turn to intercept TEX VOR/DME R-337 (T) to TEX VOR/DME R-337/21 DME, cross 21 DME at or above 11,500 ft, thence…

4.1.2. Runway 36R

In a three-runway configuration, the center runway departs straight ahead with the outboard runways turning to meet runway divergence requirements. Additionally, fanning is not an option without the ability of succeeding aircraft to turn from a proceeding departure. Therefore only a single departure was developed from the center runway.

4.1.2.1. North Departure

Once aircraft reach 11,500 ft, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., northbound).

Takeoff Minimums: Standard with a minimum CG of 272 ft to 9200 ft.

Departure Instructions: Climb on heading 002 (T) to intercept TEX VOR/DME R-358 (T) to TEX VOR/DME R-358/22 DME, cross 22 DME at or above 11,500 ft, thence…

4.1.3. Runway 01R

The following sections provide a brief description of the departure procedures to include takeoff minimums and departure instructions.

4.1.3.1. ALKOM Departure

Once aircraft cross ALKOM, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., eastbound).

Takeoff Minimums: Standard with a minimum CG of 288 ft to 9900 ft

Departure Instructions: Climbing right turn to intercept TEX VOR/DME R-046 (T) to ALKOM, cross ALKOM at or above 11,500 ft, thence…

4.1.3.2. APN Departure

Once aircraft reach APN, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., northeast, east, or southeast bound)

Takeoff Minimums: Standard with a minimum CG of 277 ft to 11,200 ft

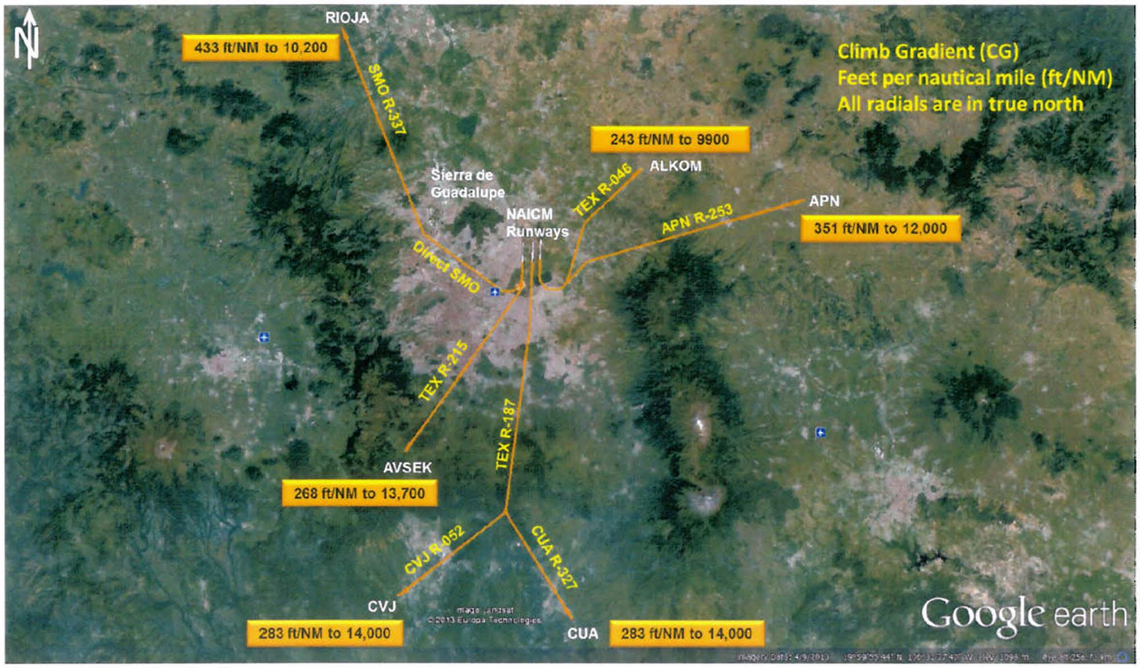
Departure Instructions: Climbing right turn to intercept APN VOR/DME R-261 (T) to APN, cross APN at or above 16,000 ft, thence…

4.2 Instrument Departure Procedures to the South

Figure 8 shows the nominal departure paths for procedures to the south for the *NAICM Alternative 1 Runway Configuration*. The following paragraphs provide information about the individual departures including takeoff minimums, departure instructions, and any associated CGs. All headings and radials denoted on these figures are based on true north.

With the runways shifted west from the previous runway configuration, a primary concern was how road traffic on the major highway and other obstacles near the beginning of the densely populated city just west of the NAICM site would impact departures from Runway 17R. For Runway 17R, trees near the departure end penetrate the departure surface by approximately 10 ft and require removal. See Figure 9.

MITRE also assumed a 15 ft vehicle on the highway for a height of 7314 ft. The departure surface height at the point of intersection with the highway is 7315 ft. City building heights at the point of intersection with the departure surface are approximately 7320 ft. The departure surface height at that point of intersection is 7323 ft. As a result, highway traffic and city buildings at the point of intersection do not penetrate the departure surface. Finally, light poles located near the highway overpass approximately 0.8 NM from the DER slightly penetrate the departure surface (i.e., 3 ft or less). See Figure 8. However, these require a CG to a height less than 200 ft above the DER. In these types of cases a CG is not published. Instead, information on these obstacles only needs to be documented (e.g., location and height) and made available to pilots (e.g., via the AIP).



Source: Google Earth

Figure 8. NAICM Alternative 1 Runway Configuration Nominal Departure Paths: South Flow

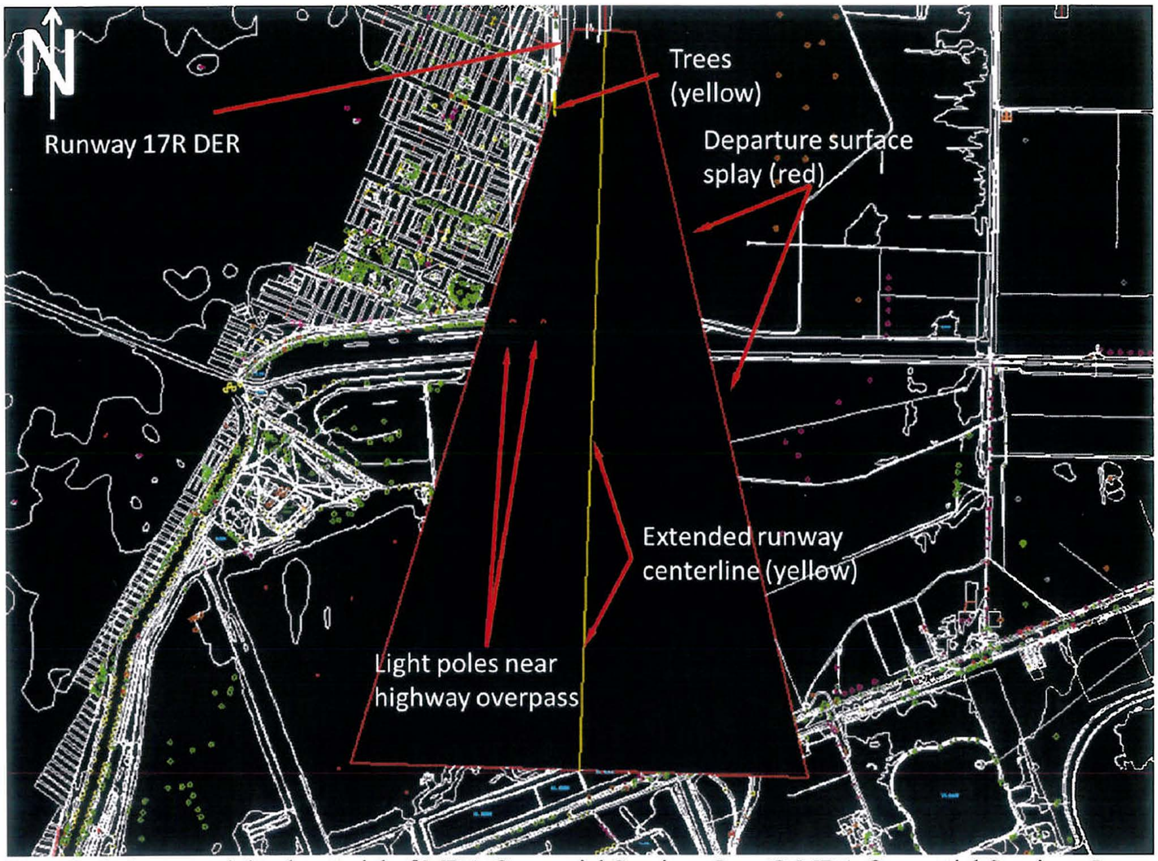


Figure 9. Runway 17R Penetrations

4.2.1. Runway 17R

The following sections provide a brief description of the departure procedures to include takeoff minimums and departure instructions.

4.2.1.1. RIOJA Departure

Once reaching RIOJA, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., northwest).

Takeoff Minimums: Standard with a minimum CG of 433 ft/NM to 10,200 ft

Departure Instructions: Climbing right turn direct to SMO VOR/DME, then via SMO VOR/DME R-337 to RIOJA, cross RIOJA at or above 11,500 ft, thence…

4.2.1.2. AVSEK Departure

Once reaching AVSEK, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., northwest).

Takeoff Minimums: Standard with a minimum CG of 268 ft to 13,700 ft

Departure Instructions: Climb on heading 182 (T) to intercept TEX VOR/DME R-215 (T) to AVSEK, cross AVSEK at or above 18,000 ft, thence…

4.2.2. Runway 18L

In a three-runway configuration, the center runway departs straight ahead with the outboard runways turning to meet runway divergence requirements. Additionally, fanning is not an option without the ability of succeeding aircraft to turn from a proceeding departure. Therefore only a single departure was developed from the center runway.

4.2.2.1. CVJ Departure

Once reaching CVJ, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., south).

Takeoff Minimums: Standard with a minimum CG of 283 ft to 14,000 ft.

Departure instructions: Climb on heading 182 (T) to intercept TEX VOR/DME R-187 (T), then via CVJ VOR/DME R-052 (T) to CVJ VOR/DME, thence…

4.2.2.2 CUA Departure

Once reaching CUA, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., south).

Takeoff Minimums: Standard with a minimum CG of 283 ft to 14,000 ft.

Departure instructions: Climb on heading 182 (T) to intercept TEX VOR/DME R-187 (T), then via CUA VOR/DME R-327 (T) to CUA VOR/DME, thence…

4.2.3. Runway 19L

In a three-runway configuration, the center runway departs straight ahead with the outboard runways turning to meet runway divergence requirements. Additionally, fanning is not an option without the ability of succeeding aircraft to turn from a proceeding departure. Therefore, only a single departure was developed from the center runway.

4.2.3.1. ALKOM Departure

Once reaching ALKOM, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., north).

Takeoff Minimums: Standard with a minimum CG of 243 ft to 9900 ft.

Departure Instructions: Climbing left turn to intercept TEX VOR/DME R-046 (T) to ALKOM, cross ALKOM at or above 11,500 ft, thence…

4.2.3.2. APN Departure

Once reaching CVJ, ATC will issue radar vectors appropriate for the filed destination of the aircraft (e.g., east).

Takeoff Minimums: Standard with a minimum CG of 351 ft to 12,000 ft.

Departure Instructions: Climbing left turn to intercept APN VOR/DME R-253 (T) to APN, cross APN at or above 16,000 ft, thence…

5. Summary

Triple independent instrument departures are feasible in both directions for the *NAICM Alternative 1 Runway Configuration*. It is important to reiterate that the feasibility of the departure procedures is dependent on the assumptions described in this document. While the procedure designs may not reflect the one and only solution, they do demonstrate what is achievable.

Table 2 summarizes the departure procedure CGs for the opening-day runway configuration. With the exception of the hard left turn departure from Runway 35L, all CGs are reasonable. MITRE considers it important however, that the DGAC and ASA discuss as soon as possible the application of these CGs with appropriate airline representatives to obtain operational feedback.

Table 2. Summary of Departure Procedure CG Requirements

North Departures		
Runway	**Termination Point**	**CG**
35L	TLC (hard left turn)	581 ft/NM to 11,100 ft
	TLC (around Guadalupe)	Standard (i.e., 200 ft/NM)
	TEX R-337/21 DME	Standard (i.e., 200 ft/NM)
36R	TEX R-358/22	272 ft/NM to 9200 ft
01R	ALKOM	288 ft/NM to 9900 ft
	APN	277 ft/NM to 11,200 ft
South Departures		
Runway	**Termination Point**	**CG**
17R	RIOJA	433 ft/NM to 10,200 ft
	AVSEK	268 ft/NM to 13,700 ft
18L	CUA	283 ft/NM to 14,000 ft
	CVJ	283 ft/NM to 14,000 ft
19L	ALKOM	243 ft/NM to 9900 ft
	APN	351 ft/NM to 12,000 ft

These procedures represent only a portion of the overall complex and integral set of actions needed to maximize their usability. Local operating and intra-facility coordination procedures will have to be developed. Controller training and additional staffing will have to be addressed as well.

The final implementation and operation of this airport in particular under this configuration has a magnitude of complexity that is a first for Mexico. As the project matures, and when appropriate, MITRE will provide guidance and assistance to ASA and other relevant authorities regarding the many elements that need to be considered in preparing for independent approach and departure procedures.

Over the coming months, depending on strategic decisions by the Mexican authorities, MITRE may examine the feasibility of CAT II/III ILS approach procedures. Area Navigation departures and Required Navigation Performance Authorization Required approach procedures may also be examined to provide design flexibility and to better-manage CGs for the *NAICM Alternative 1 Runway Configuration*. Finally, SENEAM should thoroughly review MITRE's work and the DGAC should ultimately validate and approve it.

Nevertheless, MITRE strongly recommends that Mexico adopts the *MITRE-Recommended Runway Configuration (July 2012)* solution. MITRE understands, however, that this may necessitate the acquisition of a relatively small, problematic area; yet, acquisition of that area would not only accelerate decisions, but would also ensure that the new 6-runway airport meets capacity requirements for much of this century.